

FORM PTO-1390 (Modified)  
(REV 11-2000)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371

216273US

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR

09/926615

INTERNATIONAL APPLICATION NO.  
PCT/SE00/01059INTERNATIONAL FILING DATE  
25 MAY 2000PRIORITY DATE CLAIMED  
27 May 1999

TITLE OF INVENTION

AN ELECTRIC MACHINE WITH LOW EDDY CURRENT LOSSES

APPLICANT(S) FOR DO/EO/US

Mats LEIJON

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:


1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
  - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
  - b. ☒ has been communicated by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
  - a. ☒ is attached hereto.
  - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
  - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ have been communicated by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

**Items 13 to 20 below concern document(s) or information included:**

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

Notice of Priority, Drawings (3 sheets)

Request for Consideration of Documents Cited in the International Search Report

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.492(a)(1)-(5))		INTERNATIONAL APPLICATION NO.		ATTORNEY'S DOCKET NUMBER	
09/926615		PCT/SE00/01059		216273US	
24. The following fees are submitted:				CALCULATIONS PTO USE ONLY	
BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):					
<input checked="" type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO . . . . .				\$1040.00	
<input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO . . . . .				\$890.00	
<input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO . . . . .				\$740.00	
<input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) . . . . .				\$710.00	
<input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) . . . . .				\$100.00	
ENTER APPROPRIATE BASIC FEE AMOUNT =				\$1,040.00	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input checked="" type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$130.00	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	36 - 20 =	16	x \$18.00	\$288.00	
Independent claims	2 - 3 =	0	x \$84.00	\$0.00	
Multiple Dependent Claims (check if applicable).			<input type="checkbox"/>	\$0.00	
TOTAL OF ABOVE CALCULATIONS =				\$1,458.00	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.				\$0.00	
SUBTOTAL =				\$1,458.00	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$0.00	
TOTAL NATIONAL FEE =				\$1,458.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable).				\$0.00	
TOTAL FEES ENCLOSED =				\$1,458.00	
				Amount to be refunded	\$
				charged	\$
a. <input checked="" type="checkbox"/> A check in the amount of \$1,458.00 to cover the above fees is enclosed.					
b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of _____ to cover the above fees. A duplicate copy of this sheet is enclosed.					
c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 15-0030 A duplicate copy of this sheet is enclosed.					
d. <input type="checkbox"/> Fees are to be charged to a credit card. WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.					
NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.					
SEND ALL CORRESPONDENCE TO:					
Telephone #: (703) 413-3000		Surinder Sachar			
Facsimile #: (703) 413-2220		Registration No. 34,423			
					
22850					
		SIGNATURE			
		Gregory J. Maier			
		NAME			
		25,599			
		REGISTRATION NUMBER			
		Nov. 26 2001			
		DATE			

216273US-6X PCT  
ENKEL 8637

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF:

:

MATS LEIJON

:

SERIAL NO: NEW APPLN.  
(Based on PCT/SE00/01059)

: ATTN: APPLICATION BRANCH

FILED: HERewith

FOR: AN ELECTRIC MACHINE WITH  
LOW EDDY CURRENT LOSSES

PRELIMINARY AMENDMENT

ASSISTANT COMMISSIONER FOR PATENTS  
WASHINGTON, D.C. 20231

SIR:

Prior to examination on its merits, please amend the above-identified application as

follows:

IN THE CLAIMS

Please cancel Claims 1-29.

Please add new Claims 30-65.

30. (New) A high voltage rotating electric machine comprising:

a rotor;

a stator having a slot; and

a winding having a plurality of cable layers that each include an inner conductor with

a plurality of strands and an insulation disposed about said inner conductor, said plurality of

cable layers being arranged substantially axially through said slot and substantially radially outside one another, wherein

said plurality of cable layers includes an inner cable layer and an outer cable layer, said inner cable layer being disposed in said slot radially closer to said rotor than said outer cable layer,

a larger share of strands in said inner cable layer are electrically insulated from one another than strands in the inner conductor of said outer cable layer.

31. (New) A high voltage rotating electric machine according to Claim 30, wherein:

said inner cable layer being an innermost cable layer with regard to a radial proximity to said rotor, wherein substantially all of the plurality of strands of the innermost cable layer include an electrical insulation thereabout.

32. (New) A high voltage rotating electric machine according to Claim 30, wherein:

said outer cable layer being an outermost cable layer with regard to a radial proximity to said rotor, substantially none of the plurality of strands of the outermost cable layer include an electrical insulation thereabout.

33. (New) A high voltage rotating electric machine according to Claim 30, wherein:

a portion of strands insulated from one another in the inner conductor of respective of the plurality of cable layers decreases on a cable layer by cable layer basis as a distance to the rotor increases.

34. (New) A high voltage rotating electric machine according to Claim 30, wherein:

a portion of the plurality of strands configured to have an electrical insulation within each layer of the plurality of cable layers decreases as a distance to the rotor increases on a cable layer by cable layer basis.

35. (New) A high voltage rotating electric machine according to Claim 30, wherein:

a portion of the plurality of strands configured to have an electrical insulation thereabout decreases as a distance to the rotor increases by two or more layers of the plurality of cable layers, where said distance is on a cable layer by cable layer basis.

36. (New) A high voltage rotating electric machine according to Claim 30, wherein: a plurality of slots are arranged in the stator.

37. (New) A high voltage rotating electric machine according to Claim 30, wherein: a circuit formed between the stator and rotor is configured for high voltage operation; the plurality of cable layers are configured to have an electric potential developed therein that increases as a distance between the winding and the rotor increases; and

an insulation thickness of the insulation decreases in at least one of a continuous manner and a stepwise manner as a distance from the rotor increases on a cable layer by cable layer basis.

38. (New) A high voltage rotating electric machine according to Claim 30, wherein: the insulation comprises a thin electrically insulating envelope.

39. (New) A high voltage rotating electric machine according to Claim 38, wherein: the thin electrically insulating envelope comprises an insulating lacquer.

40. (New) A high voltage rotating electric machine according to Claim 30, wherein: a strand that is insulated in the inner cable is comprised of aluminum, and an insulation on the strand is an aluminum oxide.

41. (New) A high voltage rotating electric machine according to Claim 38, wherein: a portion of the plurality of strands in said inner cable layer that are insulated are comprised of aluminum and a portion of the plurality of strands in the inner cable layer that are uninsulated are comprised of copper.

42. (New) A high voltage rotating electric machine according to Claim 30, wherein:

said inner cable layer being an innermost cable layer with regard to a radial proximity to said rotor, substantially all of the plurality of strands are comprised of aluminum; and

said outer cable layer being an outermost cable layer with regard to a radial proximity to said rotor, substantially all of the plurality of strands are comprised of copper.

43. (New) A high voltage rotating electric machine according to Claim 42, wherein:  
the winding comprises a flexible electric conductor and a casing configured to contain an electric field generated around the flexible electric conductor.

44. (New) A high voltage rotating electric machine according to Claim 43, wherein:  
the casing comprises an insulation system having an inner layer disposed on the flexible electric conductor, a solid insulation layer disposed on the inner layer, and an outer layer disposed on the solid insulation layer, wherein the outer layer is configured to have an electric conductivity higher than that of the solid insulation layer and is connected to a node having at least one of a ground potential and a low voltage potential so as to contain the electric field formed around the flexible electric conductor.

45. (New) A high voltage rotating electric machine according to Claim 44, wherein:  
the inner layer is configured to have an electric conductivity lower than the flexible electric conductor and to substantially equalize an electric field formed on an outer surface of the inner layer.

46. (New) A high voltage rotating electric machine according to Claim 44, wherein:  
the inner layer, the outer layer and the solid insulation layer are configured to have an essentially equal thermal characteristic.

47. (New) A high voltage rotating electric machine according to Claim 44, wherein:  
the inner layer and the outer layer comprise a semiconductor material.

48. (New) A high voltage rotating electric machine according to Claim 44, wherein:

the inner layer and the outer layer are configured to have a resistivity in an inclusive range of  $10^{-6}\Omega$  -  $1000\Omega\text{cm}$ .

49. (New) A high voltage rotating electric machine according to Claim 44, wherein: the inner layer and the outer layer are configured to have a resistivity in an inclusive range of  $10^{-3}\Omega\text{cm}$  -  $1000\Omega\text{cm}$ .

50. (New) A high voltage rotating electric machine according to Claim 44, wherein: the inner layer and the outer layer are configured to have a resistivity in an inclusive range of  $1\Omega\text{cm}$  -  $500\Omega\text{cm}$ .

51. (New) A high voltage rotating electric machine according to Claim 44, wherein: the inner layer and the outer layer are configured to have a resistance in an inclusive range of  $50\mu\Omega/\text{m}$  -  $5\text{M}\Omega/\text{m}$ .

52. (New) A high voltage rotating electric machine according to Claim 44, wherein: the solid insulation layer and at least one of the inner layer and the outer layer comprise a polymeric material.

53. (New) A high voltage rotating electric machine according to Claim 44, wherein: the solid insulation layer, the inner layer and the outer layer are configured to ensure adherence upon flexing and temperature change.

54. (New) A high voltage rotating electric machine according to Claim 44, wherein: the solid insulation layer, the inner layer and the outer layer comprise materials with high elasticity.

55. (New) A high voltage rotating electric machine according to Claim 44, wherein: the solid insulation layer, the inner layer and the outer layer are comprised of materials with a substantially equal E-modulus.

56. (New) A high voltage rotating electric machine according to Claim 44, wherein:

the solid insulation layer, the inner layer and the outer layer are comprised of materials with a substantially equal thermal expansion coefficients.

57. (New) A high voltage rotating electric machine according to Claim 44, wherein:  
the inner layer is configured to be in electrical contact with the flexible electric conductor.

58. (New) A high voltage rotating electric machine according to Claim 44, wherein:  
the flexible electric conductor comprises a plurality of strands, and  
at least one portion of at least one of the plurality of strands is uninsulated and  
configured to be in contact with the inner layer.

59. (New) A high voltage rotating electric machine according to Claim 42, wherein:  
the winding is configured to carry voltages greater than 10 kV.

60. (New) A high voltage rotating electric machine according to Claim 59, wherein:  
the winding is configured to carry voltages greater than 36 kV.

61. (New) A high voltage rotating electric machine according to Claim 60, wherein:  
the winding is configured to carry voltages greater than 72.5 kV.

62. (New) A high voltage rotating electric machine according to Claim 42, wherein:  
the winding is configured to be connected to a voltage greater than 10 kV.

63. (New) A high voltage rotating electric machine according to Claim 62, wherein:  
the winding is configured to be connected to a voltage greater than 36 kV.

64. (New) A high voltage rotating electric machine according to Claim 63, wherein:  
the winding is configured to be connected to a voltage greater than 72.5 kV.

65. (New) A high voltage rotating electric machine comprising:  
a stator;



a winding that includes a cable having a flexible electric conductor, an inner semiconductor layer on the flexible electric conductor, a solid insulation layer on the inner semiconductor layer, and an outer semiconductor layer on the solid insulation layer;

means for minimizing eddy current losses; and

means for containing high voltage electric field in the cable.

#### REMARKS

Favorable consideration of this Application as presently amended is respectfully requested.

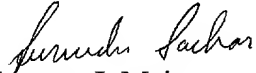
Claims 30-65 are active in the present Application; Claims 1-29 having been canceled and Claims 30-65 added by way of the present Preliminary Amendment. The new claims have been drafted in a manner consistent with U.S. practice. It is therefore believed that no issues of new matter have been raised.

The present document is one of a set of patent applications containing related technology as was discussed in "response to petition under 37 C.F.R. §1.182 seeking special treatment relating to an electronic search tool, and decision on petition under 37 C.F.R. §1.183 seeking waiver of requirements under 37 C.F.R. §1.98," filed in the holding application (U.S. Patent Application No. 09/147,325). Consistent with this decision, a copy of the decision is filed herewith. Also, an Information Disclosure Statement is filed herewith including a PTO Form 1449 with references that are included as part of the specially-created official digest in class 174. It is believed that submission of these materials and the reference to the holding application (Serial No. 09/147,325) is sufficient for the present Examiner to consider the references in the holding application, consistent with the decision.

Accordingly, examination on the merits of Claims 30-65 is believed to be in order,  
and an early and favorable action is respectfully requested.

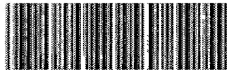
Respectfully submitted,

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216273US-6X PCT

Marked-Up Copy	
Serial No:	_____
Amendment Filed on:	11-26-2001

IN THE CLAIMS

Claims 1-29 (Canceled).

Claims 30-65 (New).

3/prts

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**AN ELECTRIC MACHINE WITH LOW EDDY CURRENT LOSSES**

10

**FIELD OF THE INVENTION AND PRIOR ART**

15 The present invention relates to a rotating electric machine having a magnetic circuit which in one of the parts of a rotor and a stator of the machine comprises an element having a slot for a winding having layers of cables extending substantially axially and arranged substantially radially outside each other, said cables comprising an inner conductor comprising a plurality of  
20 strands and an insulation externally thereof.

All types of rotating electric machines of the type with winding of a cable are comprised, i.e. such machines in which there is an insulation sheet around the conductor and the conductor is  
25 formed by a bundle of strands. All voltage ranges, high voltage as well as intermediate voltage and low voltage are comprised.

The element in the magnetic circuit with a slot for the cables may as mentioned be arranged in any of the parts: rotor and  
30 stator, of the electric machine. "Slot" is here to be given a broad sense and does not necessarily mean that this is so narrow that the element alone keeps the cables in place.

The electric machine may be arranged to function as generator and/or motor. For the purpose of example it may be mentioned  
35 that the machine could be a synchronous machine used as gen-

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three different dimensions of the cable insulation are used, such as for example for 70 kV, 100 kV and 130 kV.

It is illustrated in Fig 3 how the magnetic alternating flux generated in the teeth 7 of the element 1 upon rotation of the rotor extends around the cables arranged in the slot 8 in question. A stray flux will as illustrated by dashed lines 12 be created through the conductors in an attempt of the magnetic flux to make a shortcut. This stray or leak flux involves some inconveniences. Firstly, the main flux is reduced therethrough, which results in a somewhat lower power of the electric machine. Furthermore, the stray flux will generate eddy currents in the strands, which results in heat generation and a demand of cooling the cables, which normally takes place indirectly by cooling the sheet package surrounding them. The strands have been electrically insulated from each other for reducing the eddy current losses, so that the magnetic flux experiences thin surfaces when intersecting the conductors of the cables and thereby the eddy currents and accordingly the eddy current losses will be low. However, this means that the conductors and thereby the cable will be considerably more expensive than if the strands had been uninsulated, and the insulation is usually achieved by painting the strands with an insulating lacquer, which means a load on the environment.

## SUMMARY OF THE INVENTION

The object of the present invention is to provide a rotating electric machine of the type defined in the introduction, in which at least the disadvantage last mentioned of such machines already known has been substantially reduced.

This object is according to the invention obtained by the fact that in such a rotating electric machine a larger share of the strands of the cables closest to the other part of the rotor and the

stator are electrically insulated with respect to each other than of the cables most far away from the other part.

Thus, the invention utilizes the understanding that the magnitude of the stray or leak flux through the respective cable depends upon the relationship between the flow path closed through the cable and the alternative flow path around the cables, which means that the stray flux decreases for each cable layer in the direction away from the rotor. It has turned out that it is therefore possible to allow considerably larger continuous surfaces in the cable conductors intersected by the magnetic flux farther away from the rotor than closer thereto and thereby larger eddy current loops, since the stray flux is in any way so much lower that the eddy current losses in the conductors are kept on an acceptably low level. By electrically insulate fewer strands with respect to each other in the cables most far away from the other part, in the case discussed above the rotor, than in the cables closer to this other part, considerable costs may be saved. The costs of a strand with an insulation are normally in the order of twice the costs of a strand without insulation. Furthermore, it is when using an insulating lacquer for the insulation in this way possible to spare the environment by a considerably reduced consumption of lacquer when manufacturing the cable. Accordingly, the invention is based on the idea to concentrate on reducing eddy current losses where it is mostly needed, i.e. where the leak or stray flux is the highest.

According to a preferred embodiment of the invention substantially all strands are electrically insulated with respect to each other in the cable layer closest to said other part, which is advantageous, since the leak flux is there the highest and the need to keep the surfaces experienced by this leak flux down on a low level is then also the greatest.

According to another preferred embodiment of the invention substantially none of the strands are electrically insulated with

respect to the rest of the strands in the cable layer located most far away from said other part. Such an advantageous design of the cable in said cable layer is in fact possible, since the leak flux of that cable layer is very low thanks to the short extra way  
5 to go for the main flux around the cable layer in the element with a considerably higher magnetic reluctance.

According to another preferred embodiment of the invention the share of strands electrically insulated with respect to the rest of  
10 the strands of the cable decreases in the direction away from said other part. The advantages mentioned above of a lack of electric insulation of the strands with respect to each other where it is in fact not needed is hereby obtained. According to  
15 other preferred embodiments of the invention said decrease may take place for each cable layer in the direction away from said other part or stepwise after two or more cable layers having the same proportion or share of strands being electrically insulated with respect to each other in the direction away from said other  
20 part.

According to another preferred embodiment of the invention the electrical insulation of the strands with respect to each other is obtained by providing the respective insulated strand with an insulating thin envelope surrounding the strand, which according  
25 to an embodiment is formed by an insulating lacquer. According to another embodiment the electrical insulation of the strands with respect to each other is obtained by making such electrically insulated strands of aluminium, the surface of which is allowed to oxidate for forming an aluminium oxide layer surrounding the strand. It is in this way possible to do without the  
30 insulating lacquer undesirable from the environmental point of view, and aluminium may then advantageously be used for the strands requiring an electrical insulation with respect to each other and for example copper of the strands with no need to be  
35 electrically insulated with respect to each other. Thus, the cable or cables most far away from said other part could advanta-



geously have a conductor formed by strands of copper uninsulated with respect to each other, while the cables closest to the other part could have the conductor thereof formed by strands of aluminium. Accordingly, in the case discussed above of a high voltage generator the 70 kV-cables could for example have strands of aluminium, while the 100 kV-cables could have strands of copper.

According to another preferred embodiment of the invention said winding is at least partially formed by a cable in the form of a flexible electric conductor having an envelope able to confine the electric field generated around the conductor. This enables a reduction of electric losses, which in its turn results in a lower temperature of the cable and the surrounding element, which reduces the need of cooling and makes it possible to construct cooling arrangements possibly existing in a more simple way than without such a design of the cable. The cable may be made in the form of a flexible cable, which means substantial advantages with respect to manufacturing and mounting compared to rigid windings prefabricated and traditionally used until today. Furthermore, the use results in an insulation system with an absence of gaseous and liquid insulating material with the disadvantage adhered thereto obtained in this way.

Further advantages as well as advantageous features of the invention appear from the other dependent claims and the following description.

#### BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the appended drawings, below follows a specific description of preferred embodiments of the invention cited as examples.

In the drawings:

Fig 1 is a simplified axial end view of a rotating electric machine of the type according to the invention,

5 Fig 2 is a perspective view of a part of one end of the stator of the electric machine according to Fig 1 during the manufacturing phase thereof,

10 Fig 3 is a detail view of a part of the machine according to Fig 1 illustrating the magnetic flux paths,

Fig 4 is a graph showing the leak magnetic flux through a cable according to Fig 3 in function of the radial distance of the cable from the rotor,

15 Fig 5 is a view illustrating the construction of a cable particularly suited to be used in a rotating electric machine of the type according to the invention, and

20 Figs 6 and 7 are enlarged detail views of the innermost and the outermost cable layer in a rotating electric machine of the type shown in Fig 1 according to a first and a second preferred embodiment of the invention, respectively.

## 25 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

It is firstly illustrated in Fig 2 how the cables 9 are arranged in the slots in the element 1 by threading them thereinto. All cables are not yet in place here.

30 It is illustrated in Fig 4 how the leak flux B decreases for each position P of the cable 9 away from the rotor, i.e. with increasing distance from the rotor. The explanation thereto is that the relationship between the leak flux path and the alternative path for the magnetic flux through the element 1 around the cable layer  
35 increases continuously.

It is illustrated in Fig 6 how this understanding has resulted in a first preferred embodiment of the invention, in which the strands 13 (the entire conductor 10 is of course filled by strands, even if the figures show other things for the sake of simplicity) of the cable layer 14 located closest to the rotor are electrically insulated with respect to each other through a thin insulating layer 15 surrounding each strand, which may be of a conventional insulating lacquer. This is important for keeping the eddy current losses on a low level, since the leak flux is the highest there. However, the strands 13 of the cable layer 16 located most far away from the rotor are not electrically insulated with respect to each other, which is possible since the leak flux there is so low that the eddy current losses are still kept on an acceptably low level. It is by this possible to save financial as well as environmental resources. The strands of the outermost cable may namely be obtained to nearly half the cost with respect to the strands of the innermost cable. It is possible to design the cables between the two extreme cable layers 14, 16, so that the share or proportion of strands electrically insulated with respect to each other decreases for each cable layer or stepwise after two, three or the like subsequent cable layers having the same proportion of insulated strands in the direction away from the rotor. However, it is also possible to have for example all strands electrically insulated with respect to each other for a certain number of cable layers, for example half or two thirds thereof, and then have all strands uninsulated for the rest of the cable layers.

A second preferred embodiment of the invention is illustrated in Fig 7, which differs from the one according to Fig 6 by the fact that the electrical insulation of the strands with respect to each other has been obtained by using aluminium as material for the strands and allowing the surface of the strands to oxidate for forming an aluminium oxide layer 15 surrounding the respective strand. In the case that the strands have not been insulated

copper have been used for the strands, since this is more advantageous through the higher electrical conductivity of copper. Thus, as shown in this Figure, all strands of the innermost cable layer may be of aluminium, while the strands of the outer cable layer 16 are made of copper. The advantage of proceeding in this way for obtaining the electrical insulation of the strands with respect to each other where this is found to be necessary is that the insulating lacquer unpleasant from the environmental point of view does not have to be used. Costs for the strands, especially for the one of copper, are simultaneously saved in the same way as in the embodiment according to Fig 6.

Finally, the construction of a cable of the type particularly well suited to be used in a rotating electric machine of the type according to the invention at high voltages is illustrated in Fig 5, especially in a high voltage generator according to WO 97/45919 discussed further above. This cable has an inner electric conductor 10 with an envelope 11 able to confine the electric field generated around the conductor. This cable has an inner flexible electric conductor 10 and an envelope 11 forming an insulation system, which comprises an insulation 17 formed by a solid insulation material, preferably a material on polymeric basis, and an outer layer 18 having an electrical conductivity being higher than the one of the insulation so that the outer layer through connection to ground or otherwise to a comparatively low potential will be able to on one hand operate to equalize potential and on the other primarily enclose the electric field created as a consequence of said electric conductor 10 interiorly of the outer layer 18. Furthermore, the outer layer should have a resistivity being sufficient for minimizing the electric losses in the outer layer. The insulation system also comprises an inner layer 19, which has said at least one electric conductor 10 arranged interiorly thereof and has an electrical conductivity being lower than the one of the electric conductor but sufficient for making the inner layer to operate for equalizing potential and thereby act equalizing with respect to the electric field outside

the inner layer. Thus, such a cable is of a type corresponding to cables having a solid extruded insulation and today being used within power distribution, for example so called PEX-cables or cables with EPR-insulation. The term "solid insulation material" used means that the winding has to be without any liquid or gaseous insulation, for example in the form of oil. The insulation is instead intended to be formed by a polymeric material. Also the inner and outer layers are formed by a polymeric material, although a semiconducting one. The insulation 18 may be made of a solid thermoplastic material, such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethylpentene (PMP), cross-linked polyethylene (XLPE) or rubber such as ethylene-propylene rubber (EPR) or silicon rubber. With respect to the resistivity of the inner layer and the outer layer this should be within the range  $10^{-6}\Omega\text{cm} - 100\text{ k}\Omega\text{cm}$ , suitably  $10^{-3}-1000\Omega\text{cm}$ , preferably  $1-500\Omega\text{cm}$ . The inner and the outer layers have advantageously a resistance which per length meter of the conductor/insulation system is in the range  $50\mu\Omega - 5\text{ M}\Omega$ .

The electric load or stress on the insulation system is reduced as a consequence of the fact that the inner and outer layers of the semiconducting materials around the insulation will tend to form substantially equipotential surfaces and the electric field in the insulation will in this way be distributed comparatively homogeneously over the thickness of the insulation.

The adherence between the insulation material and the inner and outer semiconducting layers has to be uniform over substantially the entire interface thereof, so that no hollow spaces, pores and the like may be created. This is of course particularly important in high voltage applications, and a cable of this type has preferably an insulation system adapted for high voltage, suitably over 10 kV, especially over 36 kV and preferably over 72,5 kV. The electrical and thermal stresses occurring at such high voltages make high demands on the insulation material. It

is known that so-called partial discharges, PD, is in general a severe problem for the insulation material in high voltage applications. Should hollow spaces, pores or the like be formed in an insulating layer, inner corona discharges may occur at high electric voltages, whereby the insulation material is gradually degraded and the result could be electrical breakdown through the insulation. This could result in a severe breakdown of the reactor.

It is advantageous that the inner and outer layers and the solid insulation have substantially the same thermal properties for avoiding the generation of such hollow spaces or pores, in which it is particularly important that they have substantially the same coefficient of thermal expansion, so that a perfect adherence between the different layers may be maintained during temperature changes thereof and the cable expands and contracts uniformly as a monolithic body upon temperature changes without any destruction or degradation of the interfaces. The insulation layer is for example a PEX-cable of cross-linked low-density polyethylene and the semiconducting layers of polyethylene with dust and metal particles admixed. Volume changes as a consequence of temperature changes are absorbed entirely as changes of the radius of the cable and thanks to the comparatively small difference of the coefficients of thermal expansion of the layers with respect to the elasticity of these materials, the radial expansion of the cable may take place while avoiding that the layers will get loose from each other.

The cable has also to have a certain flexibility, and it is flexible down to a radius of curvature below 25 times the diameter of the cable so that bending may take place while ensuring a good adherence between the respective layers and the solid insulation. The cable is suitably flexible to a radius of curvature below 15 times the diameter of the cable, and preferably to a radius of curvature below 10 times the diameter of the cable. The E-modulus of the different layers in the insulation system should

be substantially equal so as to not induce any unnecessary shearing stresses in the interfaces between the different layers, so that a reduction of the shearing stresses that may be created between the different layers when exerting the cable to powerful bending resulting in tension stresses on the outside of the bend and compressive stresses on the inside of the bend may take place.

The invention is of course not in any way restricted to the preferred embodiments described above, but many possibilities to modifications thereof will be apparent to a man skilled in the art without departing from the basic idea of the invention as defined in the appended claims.

It would for example be well possible to use other materials than those mentioned above for electrically insulating the strands with respect to each other, and it would also be possible to imagine different combinations of electrical insulation therebetween, so that for example where the leak flux is not that high for example an electrically insulating layer is arranged around a smaller amount of strands, as for example three, for electrically insulating them with respect to another such bundle of strands and obtain a suitable restriction of the size of the surface experienced by the leak flux.

For making the electric machine described further above function at higher voltages it is essential that at least one strand of the cable is in electric contact with the inner semi-insulating layer for forming a equipotential surface, and "substantially all strands are electrically insulated with respect to each other" in the claims is intended to cover this case too.

Claims

1. A rotating electric machine having a magnetic circuit which in one of the parts of a rotor (5) and a stator (2) of the machine comprises an element (1) having a slot (8) for a winding having layers (14, 16) of cables (9) extending substantially axially and arranged substantially radially outside each other, said cables (10) comprising an inner conductor comprising a plurality of strands (13) and an insulation (11) externally thereof, **characterized** in that a larger share of the strands of the cables closest to the other part of the rotor and the stator are electrically insulated with respect to each other than of the cables most far away from the other part.
2. A rotating electric machine according to claim 1, **characterized** in that substantially all strands (13) are electrically insulated with respect to each other in the cable layer (14) closest to said other part.
3. A rotating electric machine according to claim 1 or 2, **characterized** in that substantially none of the strands (13) are electrically insulated with respect to the other strands in the cable layer (16) located most far away from said other part (5).
4. A rotating electric machine according to any of claims 1 to 3, **characterized** in that the share of strands electrically insulated with respect to the rest of the strands (13) of the cable (9) decreases in the direction away from said other part (5).
5. A rotating electric machine according to claim 4, **characterized** in that said decrease takes place for each cable layer in the direction away from said other part (5).
6. A rotating electric machine according to claim 4, **characterized** in that said decrease takes place in steps after two or more cable layers having the same share of strands (13) electrically



insulated with respect to each other in the direction away from said other part (5).

5 7. A rotating electric machine according to any of claims 1-6, **characterized** in that said element (1) having slots (8) is arranged in the stator (2) of the machine.

10 8. A rotating electric machine according to any of claims 1-7, **characterized** in that the magnetic circuit is for high voltage and the potential of the cable layers increases in the direction away from said other part (5), and that the thickness of said insulation (11) of the cables (9) increases continuously or stepwise in the direction away from said other part.

15 9. A rotating electric machine according to any of claims 1-8, **characterized** in that the electrical insulation of the strands (13) with respect to each other is obtained by providing the respective insulated strand with a thin electrically insulating envelope (15) surrounding the strand.

20 10. A rotating electric machine according to claim 9, **characterized** in that the insulating envelope (15) is formed by an insulating lacquer.

25 11. A rotating electric machine according to claim 1-8, **characterized** in that the electrical insulation of the strand (13) with respect to each other is obtained by making such electrically insulated strands of aluminium, the surface of which is allowed to oxidate for forming an aluminium oxide layer surrounding the  
30 strand.

35 12. A rotating electric machine according to claim 11, **characterized** in that the electrically uninsulated strands (13) are made of copper and the electrically insulated strands (13) are made of aluminium.

13. A rotating electric machine according to any of claims 1-12, **characterized** in that at least the cable (9) of the layer (14) closest to said other part (5) has all strands (13) made of aluminium and at least the cable of the layer (16) most far away from said other part has all strands (13) made of copper.

14. A rotating electric machine according to any of claims 1-13, **characterized** in that said winding is at least partially formed by a cable (9) in the form of a flexible electric conductor (10) with an envelope (11) able to confine the electric field generated around the conductor.

15. A rotating electric machine according to claim 14, in which the envelope comprises an insulation system, **characterized** in that the insulation system comprises an insulation formed by a solid insulation material (17) and outside thereof an outer layer (18) having an electrical conductivity which is higher than the electrical conductivity of the insulation so that the outer layer may through connection to ground or otherwise comparatively low potential be able to on one hand operate for equalizing potential and on the other substantially enclose the electric field generated as a consequence of said electric conductor (10) inwardly of the outer layer.

16. An electric machine according to claim 14 or 15, in which the envelope comprises an insulation system, **characterized** in that the insulation system comprises an insulation (17) formed by a solid insulation material and an inner layer (19) interiorly thereof, that said at least one electric conductor is arranged interiorly of the inner layer and that the inner layer has an electrical conductivity being lower than the electrical conductivity of the electric conductor but sufficient for making the inner layer to operate to equalize potential and thereby to equalize the electric field outside the inner layer.

35

17. An electric machine according to claim 15 or 16, **characterized** in that the inner (19) and the outer (18) layers and the solid insulation (17) have substantially equal thermal properties.
- 5 18. An electric machine according to any of claims 15-17, **characterized** in that the inner (19) and/or the outer (18) layer comprise a semiconductor material.
- 10 19. An electric machine according to any of claims 15-18, **characterized** in that the inner layer (19) and/or the outer layer (18) have a resistivity in the range  $10^{-6}\Omega\text{cm}$  –  $100\text{ k}\Omega\text{cm}$ , suitably  $10^{-3}$  –  $1000\Omega\text{cm}$ , preferably  $1$ – $500\Omega\text{cm}$ .
- 15 20. An electric machine according to any of claims 15-19, **characterized** in that the inner layer (19) and/or the outer layer (18) has a resistance, which per length meter of the conductor/insulation system is in the range  $50\mu\Omega$  –  $5\text{ M}\Omega$ .
- 20 21. An electric machine according to any of claims 15-20, **characterized** in that the solid insulation (17) and the inner layer (19) and/or the outer layer (18) are formed by polymeric material.
- 25 22. An electric machine according to any of claims 15-21, **characterized** in that the inner layer (19) and/or the outer layer (18) and the solid insulation (17) are rigidly connected to each other over substantially the entire interface to ensure adherence also upon flexing and temperature change.
- 30 23. An electric machine according to any of claims 15-22, **characterized** in that the solid insulation and the inner layer (19) and/or the outer layer (18) are formed by materials having a high elasticity to maintain mutual adherence on strains during operation.

24. An electric machine according to claim 23, **characterized** in that the solid insulation (17) and the inner layer (19) and/or the outer layer (18) are of materials having substantially equal E-modulus.

5

25. An electric machine according to any of claims 15-24, **characterized** in that the inner layer (19) and/or the outer layer (18) and the solid insulation (17) are formed by materials having substantially equal coefficients of thermal expansion.

10

26. An electric machine according to any of claims 15-25, **characterized** in that the inner layer (19) is in electric contact with the at least one electric conductor (10).

15

27. An electric machine according to claim 26, **characterized** in that said at least one electric conductor (10) comprises a number of strands (13) and that at least one strand of the electric conductor is at least in part uninsulated and arranged in electric contact with the inner layer.

20

28. An electric machine according to any of claims 15-27, **characterized** in that the conductor and its insulation system are designed for high voltage, suitably over 10 kV, in particular over 36 kV and preferably over 72,5 kV.

25

29. An electric machine according to any of the preceding claims, **characterized** in that it is adapted to be connected through the windings to a high voltage, suitably over 10 kV, in particular over 36 kV and preferably over 72,5 kV.

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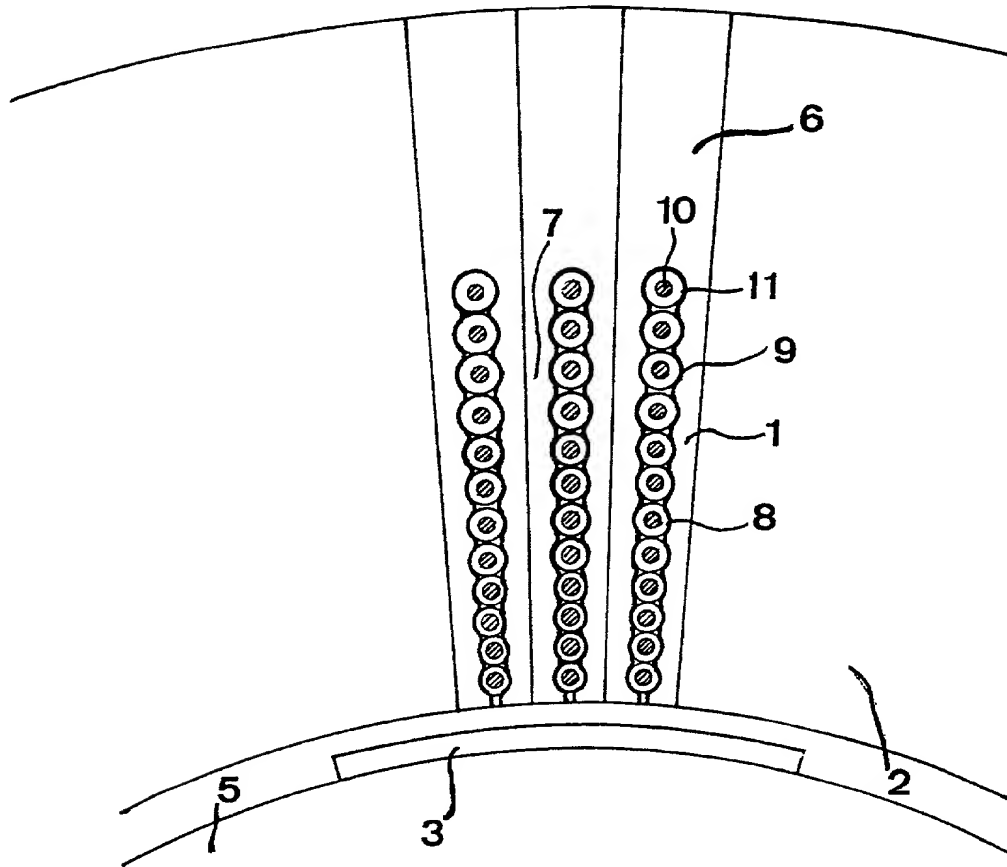
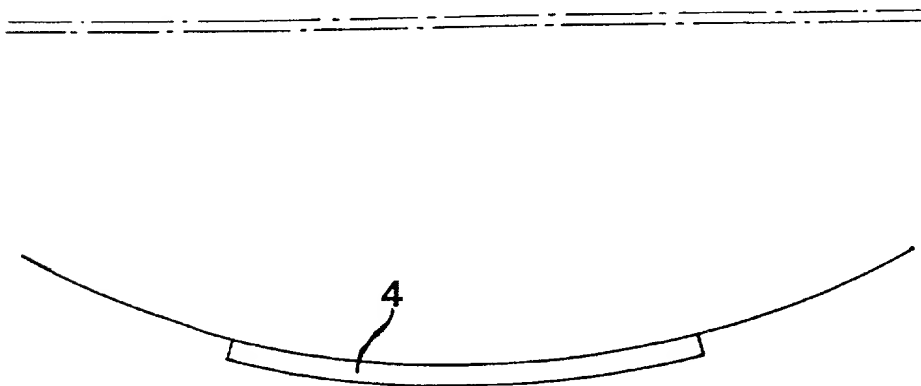


Fig 1



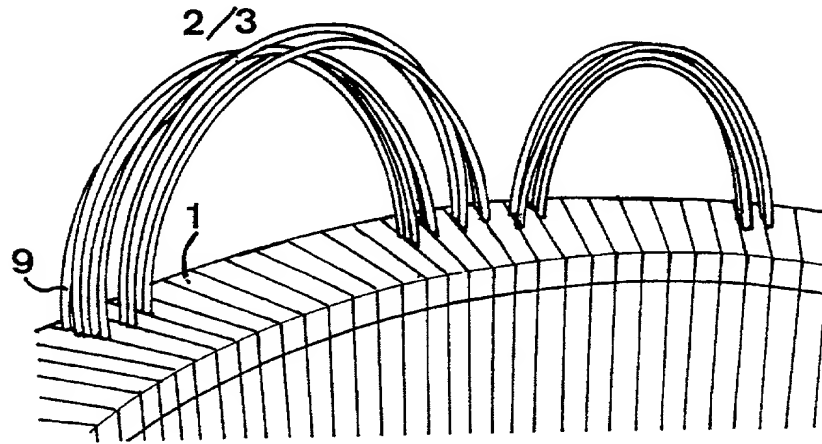


Fig 2

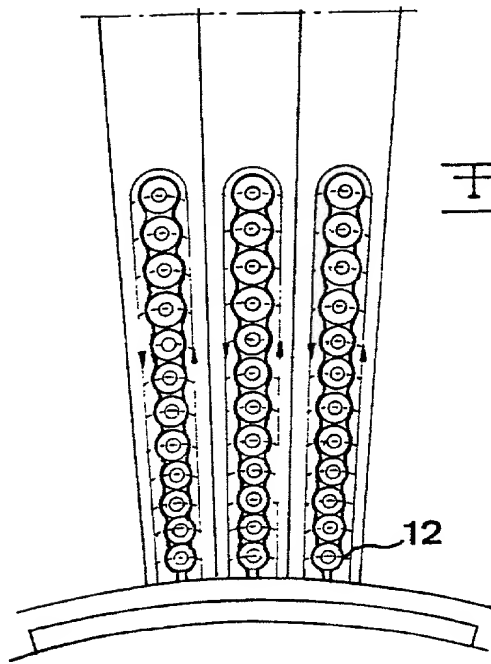


Fig 3

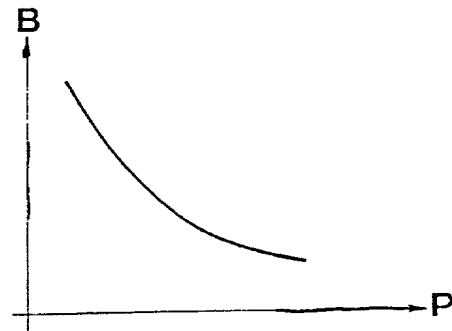


Fig 4

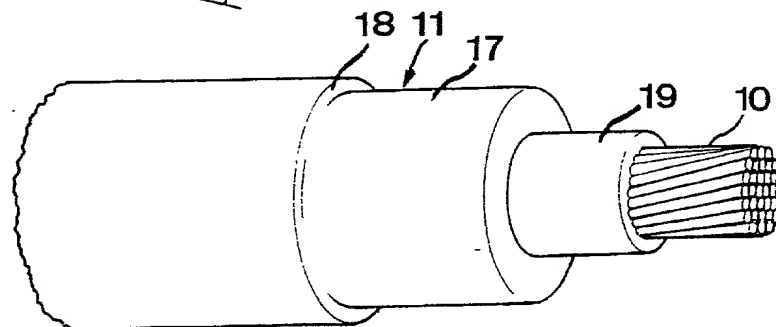


Fig 5

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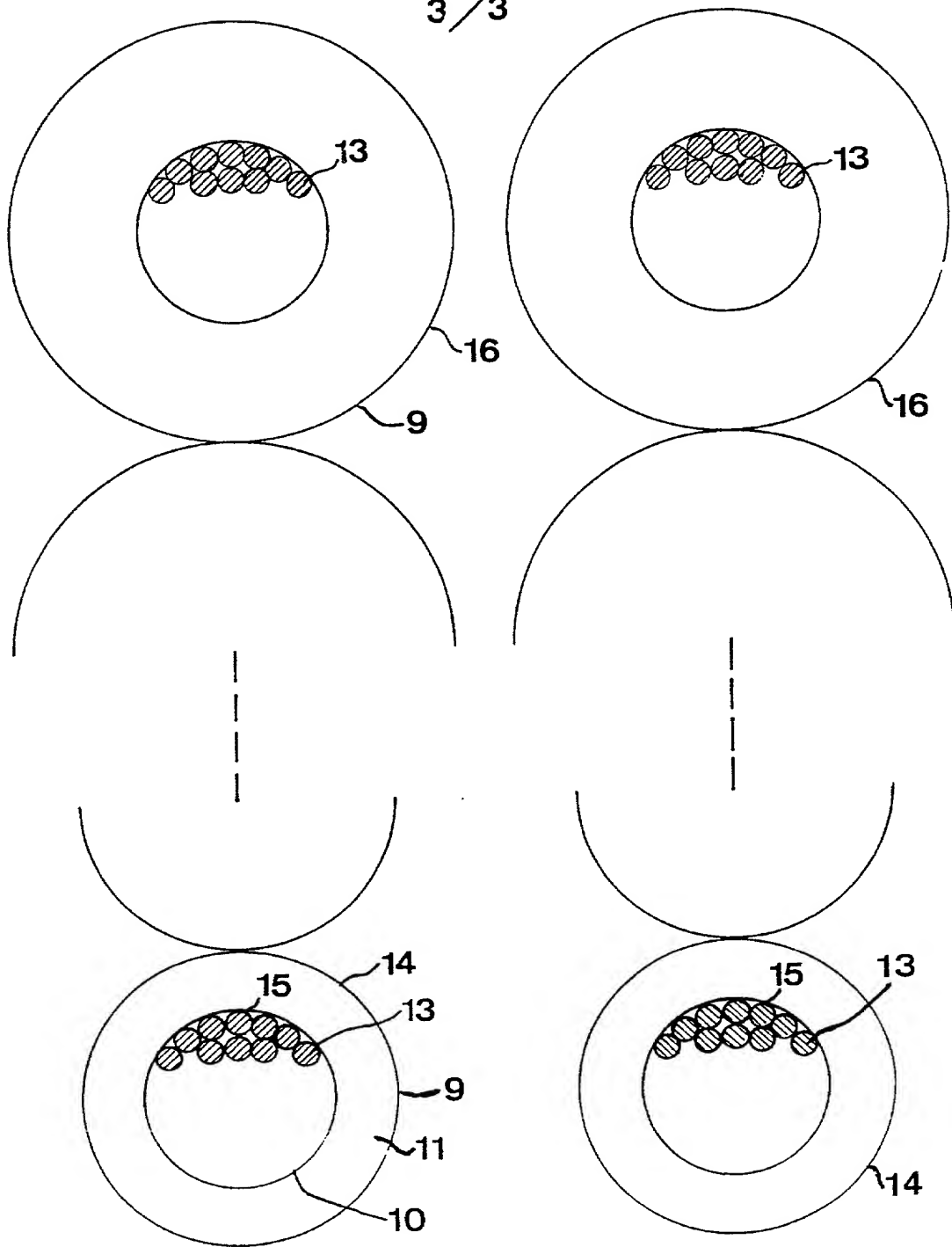


Fig 6

Fig 7

2000051992660

# Declaration and Power of Attorney for Patent Application

## Försäkran och Fullmakt avgiven i samband med ansökan om patentskydd

### Swedish Language Declaration

Som nedan nämnd uppfinnare förklarar jag att:

As a below named inventor, I hereby declare that:

Min hemvist, postadress och medborgarskap är som nedan angivits.

My residence, mailing address and citizenship are as stated next to my name.

Jag är övertygad om att jag är den ursprungliga, första och enda uppfinnaren (om endast ett namn uppges nedan) eller en av de ursprungliga och första meduppfinnarna (om flera namn anges nedan) av den uppfinning för vilken patent söks, benämnd:

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled.

AN ELECTRIC MACHINE WITH LOW EDDY CURRENT LOSSES

vars patentbeskrivning härmed bifogas om inte

the specification of which

☐ härtill bifogad

☐ is attached hereto.

☐ ingavs den \_\_\_\_\_

☒ was filed on November 26, 2001

som U.S. ansökningsnummer eller PCT  
internationellt ansökningsnummer

as United States Application Number or PCT  
International Application Number

\_\_\_\_\_ och ändrades den \_\_\_\_\_

09/926,615 and was amended on \_\_\_\_\_

\_\_\_\_\_ (eventuellt).

\_\_\_\_\_ (if applicable)

Jag förklarar härmed att jag har granskat och förstår innehållet i den ovannämnda beskrivningen och patentkrav med de eventuella ändringar som gjorts.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

Jag är medveten om min skyldighet att uppgge information av väsentlig betydelse för patenterbarhet i enlighet med "Title 37, Code of Federal Regulations, § 1.56."

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.



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Jag yrkar härmed prioritet enligt "Title 35, United States Code, § 119(a)-(d) or § 365(b)" för de(n) utländska ansökning(ar) som angivits nedan och avser patent eller uppfinnarcertifikat eller, under § 365(a) enligt ovan, för varje internationell PCT-ansökan som designeras åtminstone ytterligare ett land förutom U.S.A.; vidare har jag nedan identifierat, genom att korsa ruta, eventuella utländska patentansökningar, uppfinnarcertifikat eller internationella PCT-ansökningar som har inlämningsdatum före det inlämningsdatum för ansökan från vilket prioritet yrkas.

Prior Foreign Application(s)  
Tidigare ansökning(ar) utomlands

9901913-5

(Number)  
(Número)

Sweden

(Country)  
(País)

Jag yrkar härmed på den förmon som I enligt med "Title 35, United States Code, § 119(e)" tillkommer varje de Förenta Staternas hjälpsökan som uppräknas nedan.

(Application No.)  
(Ansökan,nr)

(Filing Date)  
(ingivningsdag)

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PCT/SE00/01059

(Application No.)  
(Ansökan,nr)

May 25, 2000

(Filing Date)  
(ingivningsdag)

(Application No.)  
(Ansökan,nr)

(Filing Date)  
(ingivningsdag)

Vidare förklarar jag att dessa uppgifter, såvitt jag vet, är sanningsenliga och alla uttalanden om information och vetande förmodas vara sanningsenliga; och att dessa uppgifter lämnats I medvetande om att avsiktligt falska uppgifter och likande kan straffas med böter eller fängelse eller bådadera enligt "Section 1001 of Title of the United States Code", och att sådanaavsiktligt falska uppgifter kan äventyra giltigheten av ansökningen eller ett därav beviljat patent.

FULLMAKT: I egenskap av uppfinnare befullmäktigar jag härmed följande advokat/er och/eller ombud att tala och svara i denna ansökan inför US Patent & Trademark Office: (Ange namn och registreringsnummer nedan).

I hereby claim foreign priority under Title 35, United States Code, § 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Priority Claimed  
Prioritetsrätt  
Krävs inte

27 May 1999

(Day/Month/Year Filed)  
(Día/Mes/Año de presentación)

☒

Yes  
Sí

☐

No  
No

I hereby claim the benefit under Title 35, United States Code, §119(e) of any United States provisional application(s) listed below.

(Application No.)  
(Ansökan,nr)

(Filing Date)  
(ingivningsdag)

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

(Status: Patented, Pending, Abandoned)  
(ärendets status: patent meddelat, ej avgjort, avslag)

(Status: Patented, Pending, Abandoned)  
(ärendets status: patent meddelat, ej avgjort, avslag)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: (list name and registration number)

# Swedish Language Declaration



**022850**

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